JACC: CARDIOVASCULAR IMAGING
VOL. 7, NO. 10, 2014

ISSN 1936-878X/$36.00
PUBLISHED BY ELSEVIER INC.
http://dx.doi.org/10.1016/j.jcmg.2014.08.002

iPIX

IMAGING VIGNETTE

CMR in the Assessment of Cardiac Masses

Primary Malignant Tumors

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CARDIAC MAGNETIC RESONANCE (CMR) PLAYS AN IMPORTANT ROLE IN THE ASSESSMENT OF CARDIAC tumors, because it combines high contrast and spatial resolution with a panoramic view of the heart and surrounding structures and an unmatched ability to characterize tissues. So, CMR assessment is frequently recommended to patients with cardiac masses to confirm the lesion, orient the diagnosis toward the benign or malignant nature, and guide the subsequent patient management.

Following the Imaging Vignette about benign primary cardiac tumors (1), here is presented a selection of images to underline the peculiar CMR features of the most frequent primary cardiac malignancies (**Figures 1 to 3**) and pseudo-masses (**Figure 4**).

Concerning the topography, morphology, and signal intensity, the features suggesting malignant nature are: invasion of extracardiac structures, involvement of >1 cardiac chamber, involvement of the right side of the heart, tissue inhomogeneity, poor definition of borders, >5 cm diameter, and presence of pericardial or pleural effusion.

To confirm the diagnosis of malignancy and to better characterize its nature, the acquisition of a perfusion study during contrast agent injection is recommended (**Figures 1 and 3**). Qualitative assessment of enhancement may help in the mass characterization, and moreover, semiquantitative analysis of enhancement curves provides additional criteria for the evaluation of tumor aggressiveness and for identification of cardiac malignancy (2).

On the other side, when thrombotic lesions are suspected, the acquisition of late gadolinium enhancement images with the specific choice of long inversion times (such as 600 ms), matching the null point of "avascular tissue," leads to a homogeneous hypointense appearance of thrombi clearly distinguishable from the surrounding myocardium (3) (**Figure 4**).

To help with the differential diagnosis of malignancies from benign tumors and pseudo-masses and to provide some skills for a further cardiac mass characterization, we composed a table that sums up the main imaging features of the masses most commonly found in the heart (**Table 1**).

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TABLE 1 Summary of Cardiac Mass CMR Features

	T1w	PDw	T2w	STIR	Cine	Contrast Enhancement	"Key Signs"
Myxoma	Iso (heterogeneous)	Iso-hyper (heterogeneous)	Hyper (heterogeneous)	No change	Hypo	Heterogeneous	Left atrium, mobile lesion
Papillary fibroelastoma	Iso	Iso	Iso	Iso	Hypo	Usually not assessable	Mobile lesion, peritumoral turbulent flow
Fibroma	Iso	Hypo	Hypo	Hypo	Iso-hypo	Early: none; 10 min: homogeneous intense	Homogeneous intense late-enhancement
Hemangioma	Iso	Iso-hyper	Hyper	Hyper	Hyper	Heterogeneous, intense and prolonged	Angioma-like contrast enhancement
Paraganglioma	Iso-hypo	Hyper	Hyper	Hyper	Hyper	Strong	High SI on t2w images
Angiosarcoma	Iso (heterogeneous)	Hyper	Hyper (heterogeneous)	Hyper	Iso (heterogeneous)	Strong	"Cauliflower" aspect on black-blood images, avid enhancement with "sunray" aspect
Rhabdomyosarcoma	Iso	Iso-hyper	Iso-hyper	Hyper	Iso	Heterogeneous	Infiltrative aspect with heterogeneous avid enhancement
Lymphoma	Hypo-iso	Iso-slightly hyper	Slightly hyper	Hyper	Iso	Mild	Infiltration without destruction of anatomic structures, progressive mild enhancement
Thrombus Acute - subacute	Iso-hyper	Iso-hyper	Iso-hyper	No change	Iso-hypo	None	Lesion adherent to hypo-akinetic segments of the heart, usually no enhancement with IR null point of avascular tissue at approximately 600 ms
Thrombus Chronic	Hypo	Hypo	Hypo			Rare	
Caseous necrosis	Hypo	Hypo	Hypo	Hypo	Hypo	Peripheral rim	Hypo in all the sequences, no enhancement (except for the peripheral rim), mitral anulus involvement

The table provides signal intensity (SI) features for each type of mass according to the cardiac magnetic resonance (CMR) sequences performed. Of note, the last table column on the right is focused on a brief description of the "key signs" characterizing each specific lesion.

Hyper = hyperintense to myocardium; Hypo = hypointense to myocardium; IR = inversion recovery; Iso = isointense to myocardium; PD-w = proton density-weighted; SI = signal intensity; STIR = short-tau-inversion-recovery; T1-w = T1-weighted; T2-w = T2-weighted.

Angiosarcoma	
Site	Parietal with expansion into cardiac chambers or pericardium
Location	Right atrium (75%) with infiltration into adjacent structures and pericardium
Typical MR features	Large infiltrating mass, heterogeneous SI due to necrosis and hemorrhage (cauliflower aspect), avid enhancement with "sunray" aspect

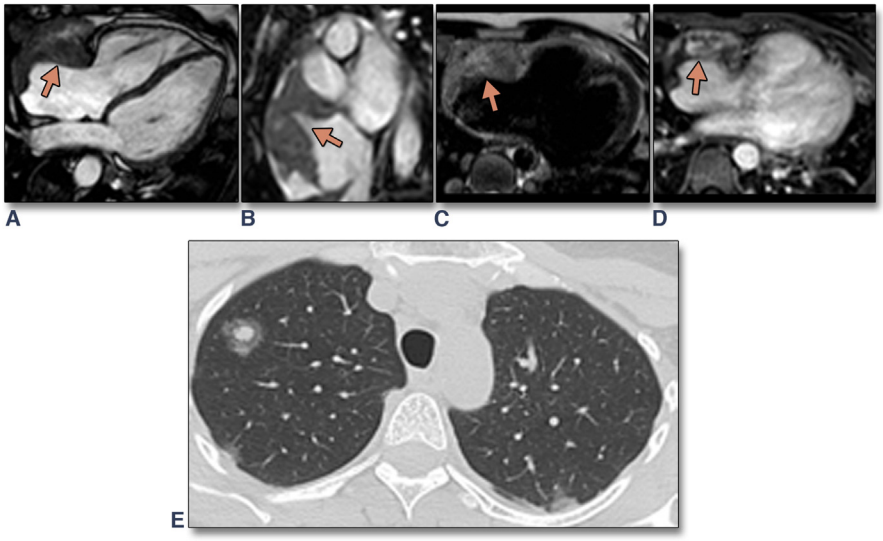

FIGURE 1 A Primary Large Angiosarcoma of the Right Atrium With Metastatic Spread to the Lung

On long-axis 4-chamber **(A)** and parasagittal **(B)** steady-state free precession (SSFP) sequences, the lesion **(arrow)** appears as a stiff mass with an infiltrative behavior, involving the anterior wall of the right atrium, the pericardium, and the right ventricle. On 4-chamber T2-weighted image **(C)**, the mass **(arrow)** presented heterogeneous high signal intensity (SI) (cauliflower aspect). At the perfusion study **(D),** a rapid and heterogeneous enhancement with a "sunray" aspect **(arrow)**, indicative of intense tumor angiogenesis, was evident. These magnetic resonance (MR) characteristics indicate the malignant nature and may suggest the diagnosis of angiosarcoma, the most frequent primary malignancy of the heart. A staging computed tomography **(E)** demonstrated several hyperdense nodules surrounded by a ground-glass halo suggestive of perinodular alveolar hemorrhage; this aspect is typical of very highly-vascularized metastasis. Biopsy performed on lung metastasis confirmed the diagnosis of angiosarcoma.

Rhabdomyosarcoma	
Site	Intramural
Location	No chamber predilection
Typical MR features	Infiltrative mass, irregular margins, tendency to central necrosis, heterogeneous avid enhancement (poorly distinguishable from other sarcomatous lesions)

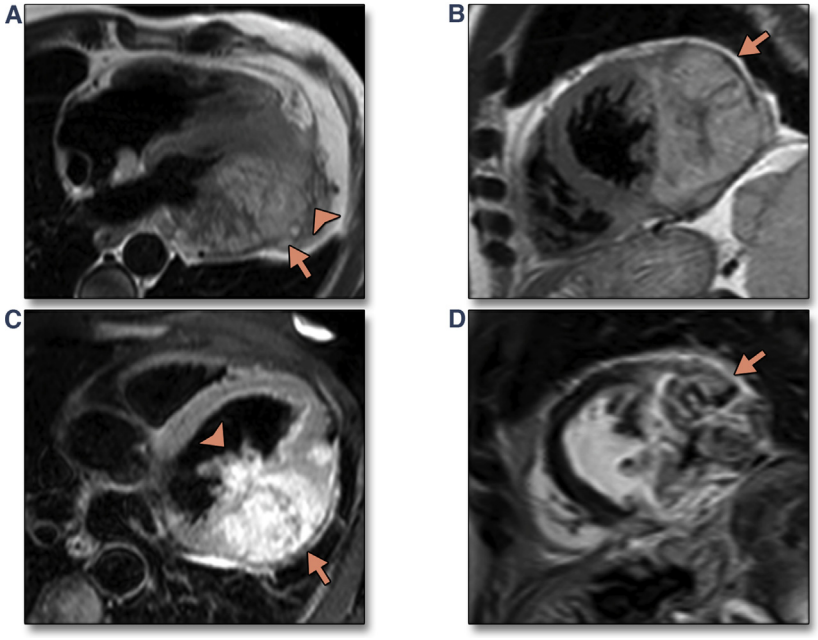

FIGURE 2 A Large Rhabdomyosarcoma of the Left Ventricle

Both on long-axis 4-chamber **(A)** and short-axis **(B)** T2w black-blood images the lesion appears as a heterogeneous slightly hyperintense bulky mass that has quite completely replaced the lateral wall of the left ventricle. On fat-suppressed T2w image **(C)** the mass resulted strongly hyperintense, probably due to its rich vascularization with possible presence of hemorrhagic components. Post-gadolinium T1-weighted inversion recovery images **(D)** confirmed the highly vascularized nature of the lesion. Note the infiltrative behavior of the mass, with involvement of the papillary muscle **(arrowhead in C)** and infiltration of the pericardium **(arrowhead in A)**. Abbreviations as in Figure 1.

Primary Cardiac Lymphoma	
Site	Frequent involvement of epicardium and extension to pericardium
Location	Variable; more frequent right side of the heart (right atrium)
Typical MR features	Diffuse infiltration without destruction of anatomic structures, pericardial effusion, frequent involvement of more than one chamber, progressive moderate enhancement

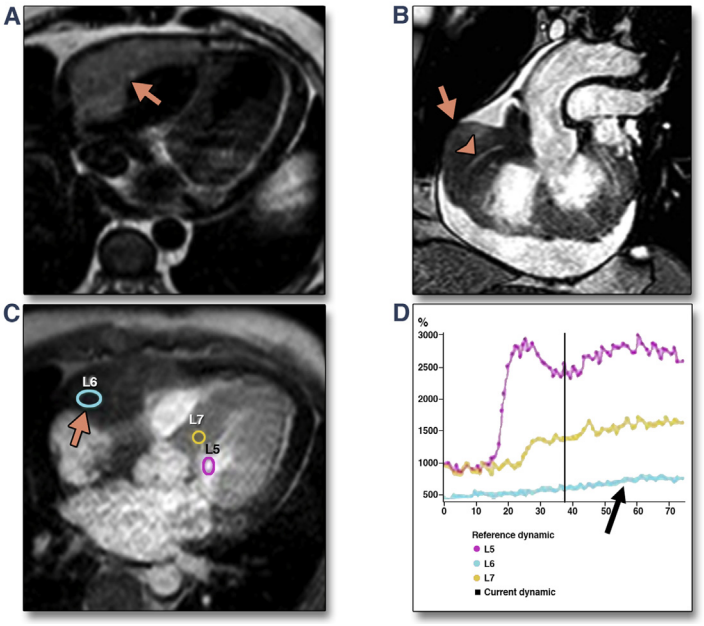

FIGURE 3 A Primary, High-Grade, Large B-Cell Lymphoma of the Right Atrioventricular Groove

An axial T2w sequence **(A)** shows a bulky mass growing anteriorly to the right chambers. On steady-state free precession sequence **(B),** the tumor is isointense and is evident the complete encasing of the right coronary artery **(arrowhead)** with preserved lumen patency; the lesion is also associated with a large pericardial effusion. These features clearly direct the diagnosis toward a malignant tumor; however, the homogeneous aspect, the relative low and progressive contrast enhancement **(C and D)**, and the preserved patency of the encased artery, are poorly compatible with a sarcomatous lesion and suggest a lymphomatous mass. Abbreviations as in Figure 1.

Thrombus	
Site	Intracavitary
Location	Left atrium (a. fibrillation) and ventricle (aneurysm), right atrium (CVC)
Typical MR features	Variable intensity depending on its age, no enhancement
Caseous Necrosis	
Site	Intracavitary
Location	Valve annulus (mitral, tricuspid)
Typical MR features	Hypointensity in all sequences, absence of enhancement

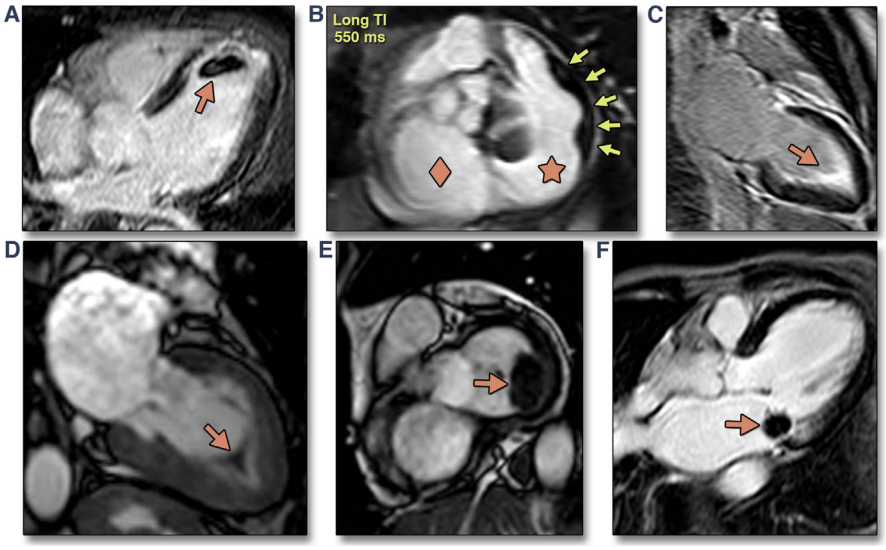

FIGURE 4 Pseudo-Masses Potentially Mimicking Cardiac Tumors

Late-enhancement imaging acquired on a long-axis plane **(A)** shows an intracavitary hypointense mass adhered to the apical septum, which is thinned and characterized by a subendocardial infarct scar. The mass is compatible with an intracavitary thrombus on an akinetic wall. **Panel B** shows a case of thin thrombotic apposition to the lateral wall of an enlarged left atrium (**star** indicates left atrium; **rhombus** indicates right atrium). Due to its thinness, the thrombus is not easily detectable on most MR sequences, whereas the acquisition of IR images with long inversion times (about 600 ms) allows the correct delineation of the homogeneously "black" thrombotic apposition **(arrows)** on hyperintense myocardium. *Löeffler endocarditis* is a specific disease frequently associated with ventricular thrombosis not related to kinetic defects. Vertical long-axis late-enhanced image **(C)** demonstrates a typical case of apical obliteration due to a strongly thickened and enhanced endocardium. This appearance definitely rules out the presence of a cardiac mass, suggested by echocardiography (not shown), and undoubtedly identifies a case of Löeffler endocarditis, a restrictive cardiomyopathy due to a flogistic response of the endocardium to a systemic hypereosinophilic syndrome. In many patients, an apical thrombosis may complicate Löeffler endocarditis, as in the case represented in **panel D** (image extracted from a post-gadolinium injection steady-state free precession cine sequence). The well-defined mass depicted in **panels E and F** has all of the typical features of a *caseous granuloma of the mitral annulus*; the strong hypointensity of this benign lesion in all sequences (balanced steady-state free precession in **E**; Inversion-recovery T1-weighted in **F**) is pathognomonic and is consistent with the presence of calcium and with its avascular nature. The location is an absolute characteristic, with a variable extension along the mitral annulus **(E)**. CVC = centra venous catheter; other abbreviations as in Figures 1 and 2.

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